

Compiling Criteria for Assessing Essential Aspects of Home Exercise Performance: A Questionnaire-Based Approach

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Abstract

Health-enabling technologies (HET) have high potential in rehabilitation to support patients performing their home exercises. The modeling of human movements as well as the modelling of quality criteria of an exercise performance remains challenging when implementing HETs. A combination of data-driven approaches and knowledge-based methods may deliver new insights. This requires structured quality assessments of concrete exercise performances from a therapists' point of view. Therefore, a structured, easy to use questionnaire to assess home exercise performances is developed and implemented. The questionnaire consists of eight items in three categories: (1-4) overall assessment of quality and quantity, (5-7) need for correction, and (8) correction hints. The collected data will be the basis for mathematical modeling of home exercise performance assessment as foundation for the development of patient supporting HETs.

Keywords:

Exercise, Upper Extremity, Data Science

Introduction

Home exercises are an effective intervention, especially for long-term treatment of various conditions [1]. Yet improperly performed home exercises are often not effective in reaching the therapeutic goals and may even be harmful to patients. Therefore, automated corrective support can be valuable especially when no physical therapist is available. Health-enabling technologies (HETs) [2] may support patients by identifying movements that need correction and giving relevant corrective feedback [3].

Over the last decades, such supporting systems have gained increasing attention. Only a few attempted to introduce quantitative measurements for the evaluation of patient improvement [4]. Furthermore, there is a need for a unified performance quantification framework [5].

One approach is to build such a framework on a combination of data-driven approaches and knowledge-based methods. Knowledge-based machine learning methods are sometimes called supervised and require a set of labeled exercise performances as training data [6]. The algorithm learns how to assess the quality of new exercise performances based on the training data as example assessments (training data) that were done previously from domain experts. How to obtain the resulting quality assessment in a way suitable for algorithms is part of this work.

Although there seems to be a consensus among physical therapists on how to assess a home exercise performance, there is no formal description or mathematical representation that can be used as basis for the development of supportive HETs. Physical therapists have to focus on many aspects when they observe patients performing their exercises. It seems that, in addition to the explicit knowledge listed in textbooks, there is also implicit knowledge about what makes a performance an appropriate one, depending on the individual patient, his/her constitution, the therapeutic goals, and much more [7]. In particular, those aspects of the assessment method that lead to a good quality performance from a physical therapists' point of view are relevant and need to be identified since they offer the most valuable information for the patient's training. An initial attempt, asking physical therapists to rate a performance in a single value, has shown that a reduction to a single score seems impossible [8].

Thus, a more complex, yet simple to use questionnaire shall be created. The development of this question set is explained in detail in this publication. The plan is to use the developed questionnaire as follows: Domain experts are going to rate the quality of several exercise performances, presented one after another. For each exercise they first get to see an instruction video presenting the exercise. Afterwards they watch the videos of the exercise performance they are asked to rate by using the corresponding standardized question set.

The aim of this study is to identify essential information about physical therapists' knowledge on how to assess home exercise performances in a simplified, structured way. For this purpose, a questionnaire for the assessment of home exercise performances in patients with musculoskeletal shoulder disorders is developed and implemented. Exercises for patients with musculoskeletal shoulder disorders are chosen, since these disorders cause severe long-term pain and affect many people [9].

Methods

The development of the questionnaire is based on expert interviews and textbook analyses. The development is undertaken on the basis of the work by Rattray and Jones [10] and on the survey guidelines of "GESIS" [11].

Gathering Information

To build up the question set, domain experts are asked to explain their thoughts with the Think-Aloud-Method while watching video recordings of concrete exercise performances.

The corresponding instruction videos are designed for patients with musculoskeletal shoulder disorders as part of the AGT-Reha-WK study [12]. While the experts explain important factors of performance assessment, key aspects get identified. Further information about the quality assessment of exercise performances is extracted from therapists' textbooks [13,14].

Generating items

The single items shall operationalize the key concepts and must be relevant and acceptable to the target group [15]. Therefore, single key aspects identified previously in the interviews and the textbook analyzes are modeled as items. Each item requires a rating scale and shall be labeled for standardization.

Reduce, group and arrange items

Redundancies in the identified items are removed. Further reduction is focused on preservation and generalization of aspects mentioned by experts with support of textbook analyzes. Finally, the items are grouped and ordered from general to specific.

Piloting

Pre- and pilot tests are conducted in order to identify any problems. Pilot-testing is conducted with respondents with expert knowledge. The Think-Aloud-Method [17] is used to identify inconsistencies and gaps in the questionnaire. In addition, the time needed to complete the questionnaire is determined. Pre-testing is conducted with respondents from study personnel to assess aspects of survey administration

Results

The question set consists of eight questions in three categories: (1-4) overall assessment of quality and quantity (5-7) need for correction and (8) correction hints.

Question set

Since physical therapists usually detect deviations in patients' movements during their daily work, the generated question items focus on detecting such deviations ad hoc, especially aspects in need of correction.

Item generation and scales

Thresholds in rating scales offer room for interpretation. When using more than three options, there has to be a lot of context to ensure valid ratings with many raters. Therefore, easy-to-use rating scales with approval and disapproval as well as the differentiation between "some deviation" and "substantial deviation" [16] are suitable for this context. To enable the respondents to provide more in-depth responses, free-text fields are included.

The answer option *No opinion* is deliberately not given because i) an answer should be possible based on the profession and ii) if absolutely necessary, the question can be.

Overall Assessment of Quality and Quantity

In general, it is unclear whether a performance can be considered ideal. Therefore, the first question shall distinguish between those performances and others by asking: *Is the performance of the exercise "in need for correction" from your point of view?* Since, the physical therapist's perspective is mainly focused on deviations and corrections, the questions ask for the need for correction in general. The answer options offer two kinds of need for correction to distinguish between

performance with optimization potential and performances in need of therapeutic correction.

When the participant reports that there is no need for correction, the presented performance is considered as ideal and no further questions are asked. The questionnaire then continues with the next instruction or performance presentation. In case there is a need for corrections the questionnaire presents the following questions.

Question 2 deals with the range of motion. Due to the state of therapy, a patient may perform the exercise correctly, but not to its full extent. This fact is the subject of the second question: *Movement range: Is the exercise performed with full range of motion?*

Question 3 distinguishes between the qualitative aspects of the movement by asking for the deviation's origin. Movement deviations can be caused by compensation movements or other movements that are not following the exercise instructions for example caused by misunderstanding the exercise instruction. It is important to identify the nature of deviations which may be associated with non-achievement of the therapeutic goal.

The fourth question serves to investigate to what extent the exercise execution is healthy and in particular not harmful.

Specific quality: Need for correction

Questions 5 and 6 are designed to inquire in a structured manner about the need for correction mentioned in the first question. It is unclear, whether the set of reasons in questions 5 and 6 covers all essential aspects for quality assessment from a physical therapist's point of view. Therefore, it is important to determine the overall quality assessment in addition to the stated reasons to overcome the possible gap of missing reasons. Furthermore, those possible missing reasons are asked for in question 7.

The concrete need for correction is subdivided in general aspects concerning the overall performance and aspects specific to both halves of the body. The assessment of the body halves can be done either together, if there is no difference between the needed corrections in the halves of the body or for each half of the body individually.

Correction hints

Question 8, in the last part, asks to present the most important corrective instructions in a free text field. Thereby, the respondent prioritizes the answers regarding the therapeutic goal, since patients have a limited cognitive capacity and the therapists usually mention the most important corrective hints first. There are no further restrictions regarding the answers' level of detail.

Online realization

The questionnaire is implemented with the online questionnaire tool SoSci Survey version 3.2.23 as an online questionnaire with multimedia content.

SoSci Survey has the advantage of supporting media in form of videos. Therefore, the exercise performances can be uploaded as single videos. The order of video presentation can be defined together with more video specific details like the name of the exercise in an additional database table. So, the videos can be retrieved dynamically from the order given by the table in a loop with the core questions and, therefore, it is easy to rearrange the presentation order or to add, exchange or delete single performances.

Table 1 – Overview of questions to record a therapists' assessment about a home exercise performance

Nr.	Question	Answer options
1	Is the performance of the exercise “in need for correction” from your point of view?	<input type="checkbox"/> Yes, there is significant need for correction <input type="checkbox"/> Yes, there is some need for correction <input type="checkbox"/> No, there is no need for correction
2	Movement range: Is the exercise performed with full range of motion?	<input type="checkbox"/> Yes <input type="checkbox"/> No
3	Movement quality: Is the performance of the exercise motorically or functionally conspicuous?	<input type="checkbox"/> Yes, it deviates from the ideal movement <input type="checkbox"/> Yes, it contains compensating / evasive movements <input type="checkbox"/> Yes, (both) it is deviating from the ideal movement and with compensatory movements <input type="checkbox"/> No, there are no deviations
4	Is the performance of the exercise potentially harmful to the person exercising?	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know. The question can only be answered with more contextual information
5	In general: Do you see a need for correction? To what extent is it present? a) Symmetry of the movement b) Harmony / fluidity of the movement c) Basic posture / starting position d) Stability in the body (spine, scapula, thorax)	<input type="checkbox"/> No need for correction <input type="checkbox"/> Some need for correction <input type="checkbox"/> Considerable need for correction
6	Halves of the body: Do you see a need for correction? To what extent is it present? a) Shoulders b) Elbows c) Hands d) Muscle tension in arms	<input type="checkbox"/> No need for correction <input type="checkbox"/> Some need for correction <input type="checkbox"/> Considerable need for correction <i>(can be answered for both halves of the body together or for each half of the body individually)</i>
7	Do you see a need for further corrections? If yes, where and to what extent?	<input type="checkbox"/> Yes, and specifically ... <i>(insert free text)</i> <input type="checkbox"/> No
8	What would you say to the person if you wanted to correct the performance of the exercise?	... <i>(insert free text)</i>

Table 1 shows an overview of the resulting question set after incorporation of the testing results. The question set is divided into five parts. Each part is presented on a separate page. On top of each page the RGB-video of one concrete exercise performance is shown in an endless loop for simple, repeated assessment without any necessary interaction by the therapists. The videos are time-synchronized and cut to present the frontal and lateral views side-by-side. A screenshot of one questionnaire page is shown in Figure 1.

The realization language is German.

Pre- and pilot testing

During the pilot testing it became clear, that the therapists mainly think about deviation and correction instead of the ideal movement. Therefore, all positive formulated questions regarding the ideal performance of an exercise got reformulated towards a deviation-focused perspective.

Discussion

We designed an approach to extract implicit and explicit knowledge of physical therapists regarding the quality of concrete exercise performances in a structured way. The questionnaire can be used as part of a quantification framework to implement a HET with respect to the claims of the physical therapists. By using the gathered structured quality assessments of the exercise performances as labels for sensor-data recordings a new way of an objective exercise definition is possible.

The items in the questionnaire are designed to assess performances of exercises regarding musculoskeletal shoulder disorders in a standing upright position. The questions themselves are based on the key aspects identified in expert interviews with domain experts like physical therapists, along with textbook analyses. As presented in [9] the assessment of an exercise performance consists of three elements: i) the quantity, ii) the quality, and iii) perceived pain. This work focused on the quality aspect. The pain aspect is not considered in the questionnaire, as this aspect has to be answered by the exercising patient. Also, the quantity is not part of this questionnaire, since it requires much more context information than is possible within this scope to assess the appropriate quantity.

Lessons learned in item generation

The pilot testing showed the focus of therapists on deviations and correction needs instead of ideals performances. So, the physical therapists have internalized the concept of the exercises and rate with that in mind. They do not try to standardize the human being they treat, instead they try to facilitate movement behavior change by giving concrete, corrective instructions. This fact supports the presented approach to generalize and learn the exercise concept in a model by achieving feedback on concrete performances.


Nearly all questions in this questionnaire are checkbox questions. The differentiation is not very finely granular. But, this way artificial thresholds in the scales are avoided and a high evaluation objectivity is ensured.

Lastly, questions with a free-text responses need to be analyzed manually and require a time-consuming evaluation. For this

flexibility in the answers, it is possible to identify poorly constructed items or propose new items for future inclusion.

Beurteilung der Übungsausführung Flieger

Bitte beantworten Sie die nachfolgenden Fragen zu dieser Übungsausführung.



Video: Übungsausführung Nr. 1 in ständiger Wiederholung

7. Körperhälften: Sehen Sie Korrekturbedarf? In welchem Ausmaß ist er vorhanden?

	Kein Korrekturbedarf	Etwas Korrekturbedarf	Erheblicher Korrekturbedarf
Schultern	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ellenbogen	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hände	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Muskelspannung in den Armen	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>

8. Sehen Sie weiteren Korrekturbedarf? Wenn ja, wo und in welchem Ausmaß?

ja, und zwar

ja, und zwar

nein

Figure 1 – Screenshot of a page from the questionnaire showing the video presentation of an exercise performance and some questions in German language

Realization

The questionnaire itself is realized as an online questionnaire with embedded video recordings. This is due to the easily feasible presentation of video recordings, which is a core concept of the realization.

With the implementation as an online questionnaire, it is easy to assemble a specific number of videos showing the performances in one survey instance depending on the available time of the surveyed therapist. Follow-up questioning of the participants is not possible through this tool. For this reason, there is an opportunity to provide additional information at the end of the questionnaire.

Another important aspect of the online realization is the fact, that the data is captured digitally. Furthermore, a reminder function for questions left open prevents accidental omission of the answer.

The realization language, so far, is German in the implementation and English for international communication. Thus, the crowd of respondents is limited to those, speaking these languages. The German language was used, since it is the national language of the first respondents. However, the questions could be implemented in any language or any

appropriate survey tool with the ability to play videos and present questions.

Generalization

When transferring the question set to other exercise types the first four questions can remain unchanged. Regarding the specific quality part further expert interviews would be needed. Possible questions for the interview are: “What are you focusing on when assessing the exercise performance?” or “What are typical errors when performing this exercise?”.

Limitations

With only 9 questions it is possible to achieve a rough quality classification. One could argue, that more questions might lead to a more specific quality assessment, but it was conceived as easy to use and a quick labeling tool and therefore should have as little questions as possible.

It is unclear, to what extent the proposed question set covers all aspects necessary to assess the quality of an exercise performance. Thus, future adaptations may be necessary, depending on the answers the domain experts give in the free text fields.

Future work

To provide basic correction instructions automatically, the quality assessments, collected with the presented questionnaire, can be used as training data in a supervised machine learning method. With the built model a classification of the learned exercises may be possible. To do this, clusters of similar performances must be found based on the motion capture data and the extent to which the quality assessments in the clusters match must be verified.

Conclusions

The combination of expert interviews and textbook analyses seems a viable approach for extracting essential aspects when assessing home exercise performances with an online questionnaire. A promising approach with potential to be generalized was designed and a questionnaire that is adaptable and extensible for other body parts was implemented. The collected data is going to be used as label for mathematical models of performance assessment as a basis for HETs. Such HETs may assist and support people practicing exercises in an unsupervised setting – like at home – by first assessing the performances’ quality in an objective manner and secondly giving corrective feedback to improve the performance quality and be advantageous to the therapeutic goal.

As a next step, the introduced questionnaire is going to be used with a set of concrete exercise performances that are rated by domain experts. The approval from the ethics committee has already been received.

The proposed questionnaire may offer new insights into the meaning of sensor-based features from a physical therapists’ point of view and hence, yield a new objective way of defining exercises to be used in HETs.

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